Proposal for the IERS

Special Bureau for Loading (SBL)

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1 Introduction

In response to the Call for Proposals for a Special Bureau for Loading (SBL) issued by the IERS on October 31, 2001, it is proposed here to set up the SBL with the task to promote, stimulate and coordinate the work and progress towards a service providing information on Earth surface deformation and gravity variations due to surface mass loading. The proposed SBL is expected to provide in near real-time a consistent global solution data set describing at least the surface deformation, gravity signal and geo-centre variations due to the various surface loading process in reference frames relevant for direct comparison with existing geodetic observing techniques. For the special case of ocean tidal loading, the existing classical products will also be made available through the SBL.

In this proposal we take into account that the main purpose of the SBL is to provide reliable, consistent model predictions of various loading signals, that have been thoroughly tested and validated. Moreover, it will be a major aim to contribute to the development of the IERS Conventions and to assure that the operational products provided by the SBL are in agreement with these Conventions.

The structure, agenda, composition, and workplan of the SBL proposed below are guided by these conditions. The proposed SBL will work in an open and integrative mode in order to assure that the products are the best not only for the geodetic community but the larger geoscience community. An attempt has been made to account for the needs of the different potential users of SBL products in the proposal.

The accuracy of the products provided through the SBL should, as much as model limitations allow, match the accuracy and precision of the space-geodetic and gravimetric observation techniques. Achieving this ambitious goal requires major scientific advances with respect to the Earth model, the theory and algorithms used to model deformations of the Earth and the observational data of surface loading. Consequently, the proposal outlines two separate agendas to be pursued in this context. The scientific agenda is required to perform the research necessary for the development of the models and algorithms and the operational agenda for the provision of validated products to potential users.

It is proposed to pursue the two agendas in parallel. The operational part is proposed to start with a demonstration project. The aim of this phase is to show that loading signals computed with available state-of-the-art procedures can be provided reliably through a web site in near-real time (NRT).

2 Description of work

The proposed work to be carried out by the SBL is separated into a total of 7 Work Packages (WP). WP1 to WP4 define the scientific agenda to be followed. They address the research oriented tasks related to the different components for the computation of deformations due to surface loading, i.e. the Earth model, the theory used to compute the Earth's response to loading, and the observations of surface loads. WP5 to WP7 define the operational agenda. They define the product-oriented routines for the operational service and the production of research data sets and address the development of operational procedures, validation of products, and distribution to the geodetic community. An overview of the WPs is given in Table 1 and the links between the different WPs are indicated in Figure 1.

Work package 1: Earth model

Up to now, most loading calculations have been carried out for Spherically symmetric, Non-Rotating, Elastic and Isotropic (SNREI) Earth models. The standard model used for these calculations is the Preliminary Reference Earth Model (PREM, *Dziewonski & Anderson,* 1981). Using SNREI models and particularly the PREM for loading calculations poses (at least) three problems, which need to be addressed in the WP in order to assure consistency:

1. The upper layer of the PREM is a global ocean of 3 km thickness. For loading calculations, this fluid layer needs to be replaced by a solid layer. Even for Body Tide Love Numbers (BTLN), significant differences were found depending on what elastic parameters were used for this replacement (Baker, 1995; private communication). It is expected that the sensitivity of the Load Love Numbers (LLN) is even bigger and care has to be taken to assure consistency of the Earth model as well as the computations.

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Table 1: Overview of the WPs.

No.	Title	Brief Description
WP1	Earth model	Address problems associated with SNREI models; provide elliptical, rotating, visco-elastic models; compile 3-d models.
WP2	Green's function and convolution	Derive Green's functions; compare the accuracy of point loading and spherical harmonic technique; define technique for computing deformation and gravity effects for SNREI and more complex Earth models.
WP3	Surface loads	Provide access to observational data on relevant surface loads.
WP4	Integrated system models	Development of integrated Earth system models for computing Earth deformation, variations in the potential and geocenter and Earth rotation perturbations in a consistent model
WP5	Operational computation of loading signals	Define standards for and carry out the operational computation of loading signals
WP6	Validation and re-analyses	Validation of operational products and computation of data sets for research purposes
WP7	Distribution	Design, implement and maintain an SBL web site for delivery of products and related information

2. The PREM gives values of the visco-elastic shear and bulk modules for 1 s and 200 s and there is no consistent way of computing values of the elastic modules. Although the expected effect on the LLNs is small, care has to be taken that a reasonable solution is used consistently.

3. Different models are used to approximate the depth-dependency of the elastic parameters in the computation of the LLNs. Again, effects are small but for consistency, a reasonable solution has to be selected.

The effect of rotation and ellipticity on the loading response are considered to be small. However, at a later stage, it may be desirable to account for these effects. Respective Elliptical, Rotating, Elastic and Isotrop (EREI) models can be derived from the PREM in a well-defined manner. Consistency with any EREI model used for other phenomena in the IERS Conventions will have to be ensured.

Viscoelastic models may also be required in order to compute accurate signals due to long-period loading such as seasonal variations, decadal variations in the ocean and terrestrial hydrosphere, glacial loading and the 18.6 yearly ocean tidal loading. If future accuracy demands will require the use of viscoelastic Earth models, then consistency with any such model prescribed by the IERS Conventions for other phenomena (e.g. body tides) will have to be ensured.

The PREM, as all other SNREI models, has a spherically symmetric crust but we suspect that at least the difference between continental and oceanic crusts will have to be taken into account to achieve sufficient accuracy of the computed loading signals. Therefore, eventually three-dimensional Earth models will be required.
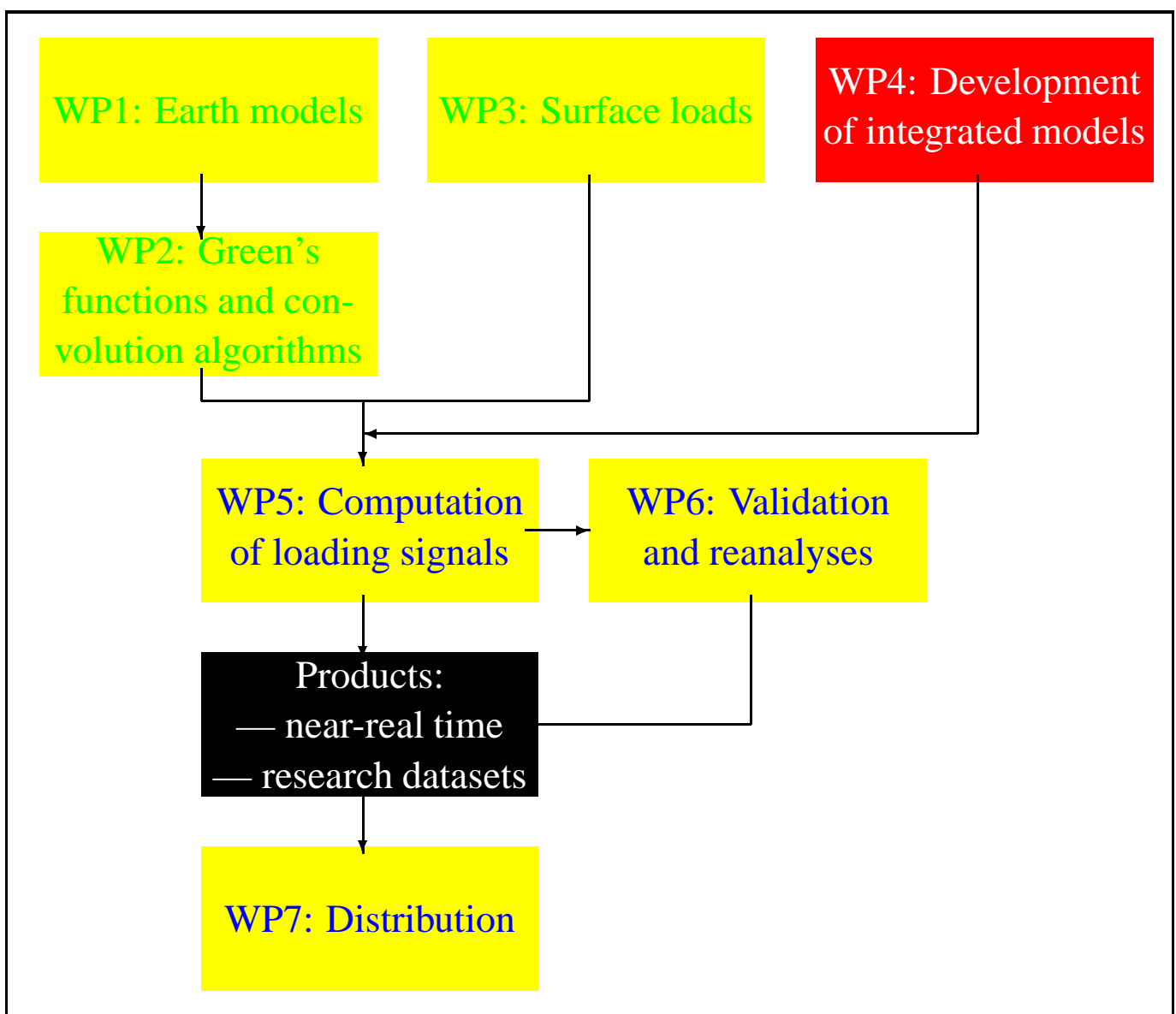
Figure 1: Proposed work packages and interlinks.

It is expected that lateral heterogeneities in the upper layers (down to approximately 100 - 150 km) have largest effects on the loading signals. A global 3-D model for the Earth's crust has been published by *Mooney et al.* (1998) with 5 x 5 degree resolution and later has been improved to 2 x 2 degree resolution (see http://mahi.ucsd.edu/Gabi/rem.dir/crust/crust2.html). Currently, work is underway to develop a 1 x 1 degree model of the upper 150 km (G. Laske, 2001, private communication).

A number of 3-D models of the Earth's mantle have been derived on the basis of seismic tomography. Examples are the models freely available from http://mahi.ucsd.edu/Gabi/3dmodels.html.

The different options for Earth models will be evaluated and the sensitivity of the LLNs and BTLNs

on the model differences will be studied. One SNREI and one 3-D model will be selected for the computation of the LLNs and BTLNs used in the operational processing. Initially, a SNREI model based on PREM will be selected for the demonstration phase (see WP5).

Work package 2: Computation of Green's functions and convolution algorithms

Computation of LLNs and BTLNs for SNREI models can be considered standard. Using the LLNs, Green's functions describing the Earth's response to point loads can be computed in the space domain according to (*Farrell,* 1972). For SNREI models, the Green's function depends on the angular distance between load and observer only.

For ocean tidal loading, which can be considered as an harmonic process, the loading signal can be computed most economically in the frequency domain (*Farrell,* 1972). The resulting products are space-dependent harmonic loading coefficients. These coefficients can be determined for all harmonic tidal constituents, for which a sufficiently accurate ocean tidal model is available.

Loading responses to non-tidal surface loads are normally computed in one of two ways

(1) **point loading approach**: In the point loading approach, a gridded surface mass is convolved with the Green's functions to determine the deformation effects (horizontal and radial surface displacements) and the gravity effect at any point on the surface of the earth. The Green's functions allow us to calculate changes in gravity caused by the deformation of the earth and the mass attraction due to the atmospheric mass everywhere except that mass directly above an individual point. This effect can be estimated using the local air pressure.

(2) **spherical harmonics approach:** In the spherical harmonic integration, the LLNs are used directly to carry out the convolution with a given surface load in the wave number domain. This approach requires the surface loads to be given as spherical harmonic expansion.

In order to estimate the computational requirements, we performed a test calculation for the entire globe using a single epoch of global surface mass data with a grid spacing of 1.0 degrees x 1.0 degrees. The program uses the Green's function approach and computes the 3-dimensional crustal motion at all land points (25193) as well as the gravity mass and deformation effects. The program ran in 7.22 minutes of CPU time on a Macintosh G4 power book running LINUX–120 minutes of user time. The program could easily be optimized to run significantly faster. As discussed in WP5, in operational mode the program would have to be run 8 times per day: 4 epochs of surface pressure data for both the National Center for Environmental Prediction (NCEP) and the European Center for Medium Range Weather Forecasts (ECMWF) data sets. Performing the point loading calculation for the global grids then is feasible as long as a 1 deg x 1 deg spatial sampling of surface atmospheric pressure remains sufficient.

Although we currently have no firm estimates of the CPU time that the spherical harmonic approach would entail, it is expected that this computational strategy is considerably faster than the point loading approach. For atmospheric pressure, which is available as a spherical harmonic expansion, the spherical harmonic approach appears reasonable. However, depending on the spatial scale of the load, unreasonably high spherical degrees may be required to match a given accuracy requirement. Thus

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we have a trade-off between precision and cpu-time required. Taking into account the response of the ocean to air pressure will result in a loss of precision compared to the point loading approach particularly at coastal sites. The loss of precision (a few percent) arises because of the land-ocean mask which is only significant for coastal sites. Hence the spherical harmonic approach will be more suitable for estimating the loading effects on a no-oceans earth model.

Related to loading on a SNREI model, the major components of this work package then will be to:

- determine the order of the spherical harmonic decomposition required to adequately represent the surface loading field;

- compare the time series determined using the point loading approach and the spherical harmonic approach (this is only an issue for the inverted barometer ocean case) –we expect the two methods will agree well at inland points but that the estimates will vary at the coasts;

- we will then need to decide if we can live with this loss of accuracy at the coastal points;

- if the loss of accuracy is unacceptable, we may have to opt for a hybrid approach where we use the spherical harmonic approach for the inland sites and the point loading approach for the coastal sites.

In computing the load signals, special attention has to be devoted to the reference frame (*Blewitt et al.,* 2001). One possibility is to provide products in various frames, for example, center of mass of the entire Earth system (common in SLR), center of mass of the solid Earth (Farrell's assumption), center of figure frame (common in GPS). To a large extent, the frame selected depends on the degree one LLN chosen. Conversion of the degree one LLN to the appropriate frame can be done prior to the computation or the frame correction can be done at the end by applying condition equations on the gridded displacements. In any case, a clear specification of the reference frame needs to be attached to the model predictions.

If it is found necessary to use EREI models, these models can be treated based on the theory developed by *Wahr* (1981) and *Plag et al.* (1996). *Plag et al.* (1996) also outline the theory required to compute LLNs for viscoelastic and non-hydrostatically pre-stressed Earth models.

A major challenge to be met by the SBL is the development and implementation of the theory for computation on laterally heterogeneous models. In this case, the Green's function becomes space-dependent and this complicates the computation of loading signals seriously. According to *Plag et al.* (1996), a perturbation method can be used to compute LLNs for 3-D Earth models, including lateral heterogeneities, rotation and ellipticity, and non-hydrostatic prestress. Gegout (2001, personal communication) has also developed a theory for computation of LLNs for laterally heterogeneous models and has implemented this. However, the different properties of oceanic and continental crusts need to be accounted for with relatively high spatial resolution if the deformation at coastal sites is to be computed. That requires not only a high resolution 3-D Earth model (see WP1) but also a theory being capable of handling the high degree and order computations. The perturbation method used by *Plag et al.* (1996) certainly will lead to computation problems for degree and order larger than approximately 100 and thus may not be adequate.

It is proposed to carry out research in order to study the sensitivity of the LLNs on patterns and features in the Earth model and to assess the potential effects of uncertainties in the 3-D Earth models on the prediction of loading signals.

Work package 3: Surface loads

It has been demonstrated that the effects of variations in atmospheric mass (*van Dam et al.,* 1994; *van Dam & Herring,* 1994), non-tidal ocean loading (*van Dam et al.,* 1997) and variations in continental water loading (*van Dam et al.,* 2001) can be observed in geodetic time series. As such, there are currently three global surface loads (atmospheric mass, continental water storage, and ocean bottom pressure) to be considered by the SBL. However, as more reliable data sets e.g. for snow mass variability, become available, these loads will be considered for inclusion into the SBL operational analysis as well.

Global atmospheric surface pressure data sets are currently provided at 6 hour intervals by the NCEP and the ECMWF. The data sets are available both as spherical harmonic expansions and as global grids (1.0 degree x 1.0 degree resolution). We will be able to obtain the NCEP Stokes Coefficients directly from the SB Atmospheres (*Salstein et al.,* 1993). We will need to subscribe to the services of NCEP and ECMWF to obtain the gridded data sets in NRT. For determining the loading effects for the last 10 years, we will use historic data compiled by the NCEP and the ECMWF. We currently have these data in our possession. For determining the effects of atmospheric mass on gravity, it may also be necessary to consider the density variations of the atmosphere with altitude (*Merriam,* 1992, ; B. Richter, personal communication). For that, the isobar data from NCEP and/or ECMWF is required. The SBL will archive the isobar data and will be able to go back and recalculate the density effect to gravity if the community decides this correction would be useful.

In the context of the atmospheric pressure loading effects, the response of the ocean to atmospheric forcing needs to be considered. Currently, only two simple models are used for describing the atmosphere-ocean interaction at these time periods: 1) no oceans and 2) inverted barometer ocean. We propose to operationally generate global loading effects using both of these models. However, neither alternative results in high accuracy and, particularly for broad coastal regions, both assumptions may be insufficient. Therefore, more complex models for the ocean response to air pressure and also wind will have to be considered providing estimates of ocean bottom pressure.

Currently, estimates of ocean bottom pressure or non-tidal ocean loading are not available in NRT as they are normally determined from Ocean General Circulation Modeling (OGCM). The SB Oceans does not currently contain any ocean-bottom pressure fields. Studying ocean-bottom pressure is an active area of investigation and investigators are reluctant to deposit their data in a public archive until they have published the results of their investigations. We currently have access to a 3 year set of modeled ocean-bottom pressures (*Chao & Fu,* 1995). This data set covers the time period 1992-1994. We can use the data set to determine the annual amplitude of the non-tidal ocean loading signal at the global sites.

In cooperation with the SB Oceans, we will make an attempt to stimulate the set-up of an operational OGCM driven by atmospheric forcing or a coupled atmosphere-ocean model in order to get access to ocean-bottom pressure in NRT. Current development indicates that such a model may be a surge and tide model. In this case, the ocean-bottom pressure field would include tidal effects and using

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this pressure field would make additional ocean tidal loading corrections obsolete. However, in this case consistency with Earth tidal effects modelled according to IERS Conventions will require careful considerations.

To estimate the effects of water storage on continents, we will use a global gridded (soil moisture+snow mass) data set generated at the National Oceanic and Atmospheric Administration Climate Prediction Center using the method described by (*Huang et al.,* 1996). The grid dimensions are 192 degrees longitude x 94 degrees latitude. No attempt is made to estimate variability on the Antarctic continent. Global, monthly results exist for 1979-1993. We also have access to a second model of continental water storage. (We are currently requesting permission to use this model operationally within the SBL.) This model provides monthly estimates for groundwater, soil moisture and snow on a 1 degree x 1 degree global grid (*Shmakin & Milly,* 1999). The data set covers the time period 1978-1998. Using these two data sets we will generate historic estimates of the loading time series. C. Milly (personal communication) has indicated that he has plans to update this model to the present. It is unclear whether the hydrological models are accurate enough to allow the associated load to be estimated with any confidence. We will need to take this fact into account before releasing any load estimates due to continental water storage to the public.

Work package 4: Integrated Earth system models

Matching the accuracy expected for space-geodetic techniques within the next few years may require that we compute surface deformation, gravity changes and other relevant parameters in a consistent, integrated Earth system model. Initial considerations concerning a modular model have been published by *Jüttner & Plag* (1999). At the current stage, it is not considered appropriate to give high priority to the development of integrated models. However, WP4 is introduced here to signal that the development of integrated Earth system models may turn out to be unavoidable.

Work package 5: Near-real time product generation

It is proposed that the SBL initially concentrates on the computation of atmospheric loading effects on geodetic time series in the frame of a demonstration project. The aim of this phase is to show that state-of-the-art products can be provided reliably through the SBL web site (see WP7). The initial NRT products will be flagged as a product under development made available for scientific research. Currently, the state of the art does not warrant setting up operational products. As a result of WP1 and WP2, it is likely that during the first year of the SBL, significant changes will take place in the algorithms and routines used for the computations. Moreover, more complete datasets for surface loads are likely to become available as a result of WP3 and the interaction with the other SBs.

For many geographical regions, atmospheric loading has a relatively long spatial scale. Therefore, it is proposed to set up an initial service which provides four to six times a day a global grid of surface displacements due to atmospheric loading. For most regions, a spatial resolution on the order of 1 degree may be sufficient.

Initially, the grid will be computed based on a SNREI model using the elastic structure of the PREM. Global grids or spherical coefficients of the surface atmospheric pressure field will be used as input assuming for the ocean both no response and an inverse barometer response to the pressure loading.

After a successful demonstration phase and the necessary developments in WP1 to WP3, routines for the computation of Version 1 NRT products will be specified and implemented.

The primary operational computations will be carried out at NMA. Research datasets computed according to routines specified by the SBL may also be contributed by other members of the SBL (see also WP7).

Work package 6: Validation and reanalyses

A fundamental role of the SBL will be providing results that as accurately as possible represent the actual deformation and gravity changes driven by surface mass loading. The best way to validate the procedures and data sets adopted by the SBL is to compare the modeled loading effects with geodetic time series. This will provide some information on the accuracy of the loading data sets and the earth models. Because GPS is the most globally distributed geodetic technique, we will initially compare our modeled deformations (vertical and horizontal) with the sinex combination results of G. Blewitt (for a complete description of the method and the data set used, see *Davies & Blewitt* (2000), and *van Dam et al.* (2001)). Based on selected high-quality IGS sites, NMA is currently carrying out a reanalyses in order to provide homogeneous satellite orbits, clocks and EOPs. With precise point positioning, homogeneous time series of a globally distributed network of GPS sites will be created for the time interval 1996 - 2001. These time series will also be available to the SBL for validation purposes.

Additional validation through VLBI, SLR and DORIS observations will be stimulated through interaction with the dedicated international services.

For a validation of the gravity loading corrections, we will work with the superconducting gravimeter community (approximately 30 globally distributed sites) to compare our model estimates with the observations. Here, cooperation with the Global Geodynamics Project (GGP) will be sought.

We will compare our predictions of geocenter motion with those observed using low earth orbiting satellites and made available by the SB Geocenter.

Depending on the progress in WP1 - WP3, research datasets covering the interval from at least 1996 to the present will be computed for different Earth models and surface load contributions. These datasets will be made available as time series for selected locations (e.g. VLBI, SLR, DORIS and IGS sites) or, if possible, as global grids.

Work package 7: Web-based distribution of products

The main interface between the SBL and users will be through a web site providing access to all loading predictions as well as documentation of the datasets and the underlying algorithms used in the computations. The primary operational computations will be undertaken at and made available through the primary SBL web site maintained by NMA. An identical mirror site will be established at the European Center for Geodynamics and Seismology (ECGS) in Luxembourg and at a site to be selected in the United States.

It is proposed to include at least the following elements in the web site:

- access to NRT datasets (grids and/or spherical harmonic coefficients) of loading predictions for a certain time interval back in time;

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- access to various loading predictions for research purpose starting from e.g. 1 January 1996 and computed with different models, algorithms, and surface loads; either as time series or as grids;

- access to ocean tidal loading coeficients through hot links to existing web; sites

- documentation of operational and research datasets;

- eventually, utilities for on-line generation of time series of loading for an arbitrary station;

- bibliography.

The list of available products will eventually include but is not limited to:

- Ocean tidal loading coefficients for selected sites or generated on request for arbitray sites

- Estimates of the radial and horizontal displacements, and estimated gravity changes predicted from the NCEP and ECMWF surface pressure fields. Initially, these results will be provided in two forms 1) global gridded estimates (2.5 x 2.5 degree or better) and 2) estimates for all ITRF and additional IGS sites.

- Estimates of the differences in the loading signals computed with the two surface pressure fields in global gridded format.

- Historical estimates of the deformation and gravity changes due to surface pressure.

- Depending on the required cpu time, historical global gridded deformation and gravity fields due to surface pressure changes.

- Historical estimates of deformation and gravity changes from the global water storage models.

- Historical estimates of deformation and gravity changes from the ocean bottom pressure models.

In the case of the atmospheric loading estimates, results for both the case of no oceans and the inverted barometer ocean will be generated. Historical estimates will be made available as time series for all ITRF and additional IGS sites. As new sites are added, the historical time series will be generated for these sites as well. Depending on the required cpu time, the historical estimates will also be made available as global grids. These grids will allow us to take into account the loading signal at stations not included in one of the global networks (e.g. EUREF sites, GPS sites at tide gauges, or even campaign sites).

At NMA a web server will be set up together with an identical backup server. Operational computations will be carried out behind a firewall and products will be made available to the open web server. All hardware will be operated under LINUX.

At ECGS, a LINUX PC will be provided to establish a mirror site for distribution of the results.

3 Work plan and timeline for first year

- 1 February 2002: Official establishment of the SBL, start of WP1, WP2, WP3, WP5, WP6, WP7.

- Week 17 2002: First meeting of the SBL team at EGS 2002, Nice, France.

- 1 June 2002: Start of NRT demonstration project

- 1 July 2002: a work plan for the further progress towards more complex loading models is available.

- 1 December 2002: Standards for Version 1 products are available.

- 1 January 2003: Initial service providing Version 1 NRT products (at least global grids of surface deformations and gravity changes due to air pressure loading on a SNREI Earth) are available. The grids can be accessed through a web page.

4 Proposed service operations and timeline

It is proposed here to provide an operational service for all geodetically and geophysically interesting signals due to surface loads. The list of relevant variables includes but is not limited to horizontal and vertical displacements, gravity changes, changes in the geoid, motion of the geocenter, and polar motion. Additionally, surface load induced relative sea level changes and changes in the length of day may become of interest. Global gridded datasets with sufficient spatial and temporal resolution and time series for specific locations will be the basic means of providing these variables. All products will be computed consistently with the accepted IERS Conventions.

The necessary spatial and temporal resolution will depend on the accuracy requirements and thus will change over time. At any time, the resolution will be selected according to the accuracy requirements but will also take into account the available cpu-time and the amount of data to be stored.

Access to ocean tidal loading will be made available through links to existing web pages providing loading coefficients in agreement with the IERS Conventions.

As mentioned in Section 2, substantial progress is needed (except for ocean tidal loading) to provide the products with an accuracy matching the accuracy and precision of the geodetic techniques. Moreover, the anticipated developments of these techniques over the next years will pose even higher demands on the models and algorithms used in the computation of loading signals. Therefore, the initial version 1 products will be more of research value than being useful for e.g. corrections of station motion in real time positioning and meteorological applications of GPS.

Without falling into prophesy, it is difficult to estimate when the necessary progress will be made to provide sufficiently accurate products in NRT. Therefore, we limit ourselves here to a short term time-line. We plan to set up a demonstration phase starting on 1 June 2001. The goal of the demonstration

phase is to show that loading signals can be computed and made available in NRT. The minimum model for the demonstration phase is based on a SNREI model using the global atmospheric pressure field as input. The minimum product will be a global grid of radial surface displacement for both no ocean and and inverse barometer ocean.

We plan to end the demonstration project by the end of 2002. It is planned to start operational production of an extended list of products from 1 January 2003 according to standards developed by the different WPs.

5   Interface between the SBL and the existing SBs

The effectiveness and efficiency of the SBL depends crucially on coordinating its tasks with the tasks of the existing SBs. The Atmosphere, Oceans, and Hydrology SBs have agreed to provide the observational data required by the SBL for computing the different loadings effects. The Atmosphere SB, as part of their charter, regularly compares the different operational atmospheric data sets. The results of these comparisons are important for determining the reliability of the loading estimates. There also needs to be a close interaction between the Core, Mantle, and Geocenter SB's in development of appropriate earth models. As stated in WP6 a significant task of the SBL will be to compare geodetic time series (crustal deformation, geocenter motion, and gravity field variability) with model outputs. Comparisons of model predictions with actual deformations will provide information that can be used to perhaps modify the Earth models. The Tide SB provides tidal predictions to the community for a number of tidal models. These models will be used to estimate the ocean loading effects.

The proposed SBL is very complementary to the existing IERS SB's. However, to avoid duplication of effort and to increase efficiency it is mandatory that the SBL interfaces extensively with the existing groups. Therefore, it is considered fundamental that the chairs of these existing SB are members ex-officio of the SBL. Their presence on the SBL will allow us to define and maintain the interface between the SBL and the other SBs in the most efficient way.

6   Contribution of the SBL to the IERS Conventions

The IERS conventions currently do not give stringent recommendations on how to estimate or treat the loading signals in geodetic data analyses. It appears, however, timely to set up a structure for formally evaluating the different procedures and data sets. These results will provide a standard for a future conventional treatment of loading in all IERS analyses (and non-IERS analyses). Providing the loading corrections to the geodetic community will perhaps reveal limitations in the models and methods. Thus the standards will evolve as new data and results warrant. The proposed SBL will be prepared to take a lead in providing the required input for future versions of the IERS Conventions.

7 Interface of the SBL to international services

The proposed membership of the SBL has direct personal links to the IGS (member of Governing Board and Associated Members) and the IVS (Associated Member). These links will provide a close coordination of the activities of the SBL with the requirements of the IGS and the IVS. An attempt will be made to establish a personal link to the ILRS and the IDS in order to ensure that the requirements of Laser Ranging and DORIS for information on loading are taken into account. Four of the proposed SBL members are also actively involved in the GGP.

It is planned to involve the services actively in the validation of the products of the SBL (see WP6).

8 Promotion plans

Promotion of the SBL will use all means available through the IERS and the GGFC. The dedicated web sites of the SBL providing access to the products and additional information provided by the SBL will be linked to both the IERS and GGFC sites.

Moreover, the SBL will be promoted by the members through presentations at major international scientific conferences. The scientific work carried out in the frame of the SBL will be published in appropriate journals pointing out the role of the SBL in stimulating the studies.

9 Role of the members

As the chair of the SBL, Tonie van Dam will coordinate the overall activities of the SBL. She will stimulate and contribute to the scientific progress and the research required for the goals of the SBL. Particular emphasis will be on validation of methods and products. Together with additional staff at ECGS, she will provide a mirror site to the main processing center located at NMA and she will contribute to the production of research data sets.

Hans-Peter Plag, co-chair, will coordinate the operational activities of the SBL. In particular, together with Halfdan P. Kierulf and additional staff members at NMA, he will provide the main processing center for NRT computations and also contribute to the production of research data sets.

Hans-Georg Scherneck will continue to provide ocean tidal loading coefficients in agreement with IERS Conventions on the established web page (http://www.oso.chalmers.se/~loading), which will be linked to the SBL.

All members of the SBL will contribute, each in the specific field of expertise, to the work specified in Section 2. It is planned to assign for each WP a leader at the first meeting of the SBL, and it is expected that different members will lead the different WPs.

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15

A   CVs of key scientists

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Education: 1991, PhD Geophysics, University of Colorado, Boulder, CO, U.S.A.

Employment History:

2000 - present	Research Geophysicist, European Center for Geodynamics and Seismology; Scientific Collaborator National Natural History Museum of Luxembourg
1993-2000	Research Geophysicist, Geosciences Laboratory NOAA/NGS
1998-1999	Visiting Scientist, Royal Observatory of Belgium
1996-2000	Technical Leader of the NOAA/NGS Absolute Gravity Group
1992-1993	with NVI (a NASA/GSFC contractor) working in the area of space based geodetic observations and their error sources; began a project to investigate sea level rise-land subsidence in the Chesapeake Bay
1991-1992	with MIT as a post-doctoral fellow focusing research in the area of error sources to space based geodetic techniques and atmosphere-ocean interactions
1982-1992	with the University of Colorado as a Research Assistant

Participation in Scientific Programmes and other relevant activities:

2001 - Present	UNAVCO NAVSTAR Consortium
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1998 - 2000	AGU Geodesy Section, Secretary
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1999 - Present	IAG Secretary Section XIV, Crustal Deformation
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Relevant activities:

1988 - 1995	Participation in the LAGEOS-II-Programme of NASA and ASI
1989 - 1999	Member of the WEGENER-Consortium and participation in the DOSE-Programme of NASA
1995 - 1999	Chairperson of the Science Panel of the WEGENER Board
1989 - 1997	Participation in the German national Earth rotation research programme
1993 - 1994	Subcontractor of the EU project SELF
1995 - 1999	Contractor of the EU project SELF II
Since 1994	Member of the Editorial Board of the *Journal of Geodynamics*
Since 1992	Several times convener at annual meetings of the EGS and the German Geophysical Society as well as the IUGG assemblies
1996 - 2000	Secretary of the EGS subsection II.5: "Geodetic aspects of global change phenomena"
Since 1996	Editor (for Geodesy) of *Physics and Chemistry of the Earth*
Since 1997	Member of the Ny-Alesund Science Manager Committee (NySMAC)
Since 1997	Responsible Scientist in the EU TMR Project "VLBI-Europe" and the Large Scale Facility Ny-Alesund
1998	Organisation of the WEGENER 98 meeting in Norway
1998 - 2001	Chair of the COST Action 40 "European Sea Level Observing System (EOSS)"
Since 1999	National Delegate, COST Action 716: "Exploitation of ground- based GPS for climate and numerical weather prediction applications", co-chair since 2000
2000	Organisation of the Second IGS Network Workshop and the COST 716 Workshop "'Towards operational GPS-Meteorology'" in Oslo, Norwegen
Since 2000	Secretary of the EGS subsection II.B2: "'Global and Regional Interdisciplinary Networks'"
Since 2000	National Delegate, IAG Commission V and XIV.
Since 2001	Director of the Central Bureau of the European Sea Level Service (ESEAS)

B List of Acronyms

Acronym	Explanation
BTLN	Body Tide Love Numbers
DORIS	Doppler Orbitography and Radio positioning Integrated by Satellite
ECMWF	European Center for Medium Range Weather Forecasts
ECGS	European Center for Geodynamics and Seismology
EOP	Earth Orientation Parameters
EREI	Elliptical, Rotating, Elastic and Isotrop
GGP	Global Geodynamics Project
GPS	Global Positioning System
IGS	International GPS Service
ITRF	International Terrestrial Reference Frame
LLN	Load Love Numbers
NCEP	National Center for Environmental Prediction
NMA	Norwegian Mapping Authority
OGCM	Ocean General Circulation Modeling
PREM	Preliminary Reference Earth Model
SB	Special Bureau
SBL	Special Bureau for Loading
SBT	Special Bureau Tides
SLR	Satellite Laser Ranging
SNREI	Spherically symmetric, Non-Rotating, Elastic and Isotropic earth models
VLBI	Very Long Baseline Interferometry
WP	Work Packages
3-D	three-dimensional